

Exploring APS parameters in view of the user experiment

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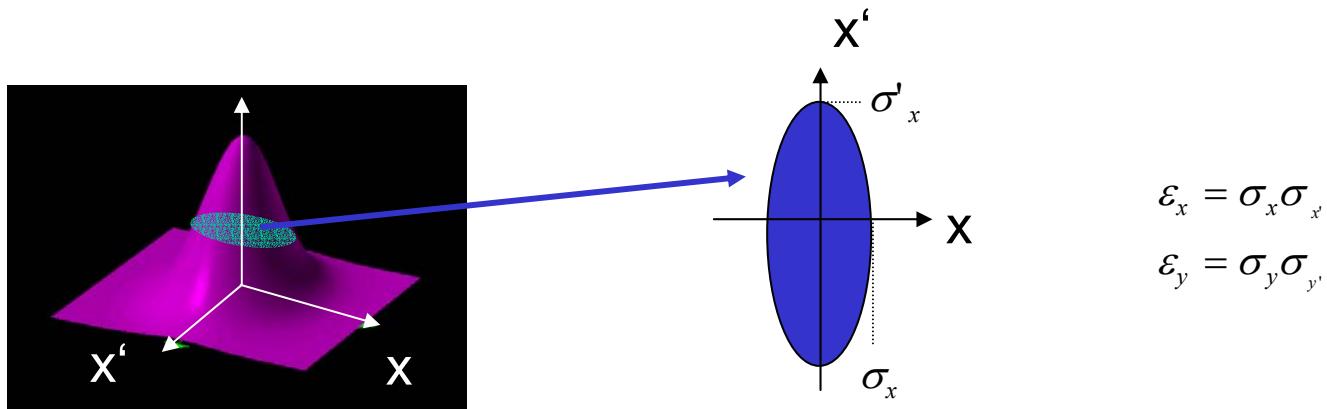
SRI-CAT

Electron beam phase space

Electrons transverse probability density

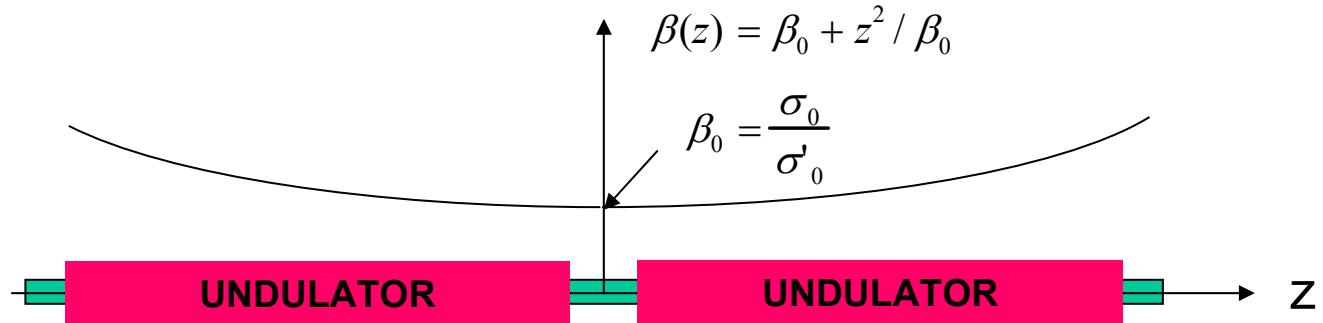
$$P(x, x', y, y') = \frac{1}{4\pi^2 \sigma_x \sigma_{x'} \sigma_y \sigma_{y'}} \exp\left(-\frac{x^2}{2\sigma_x^2} - \frac{x'^2}{2\sigma_{x'}^2} - \frac{y^2}{2\sigma_y^2} - \frac{y'^2}{2\sigma_{y'}^2}\right)$$

Emittance - volume in a phase space

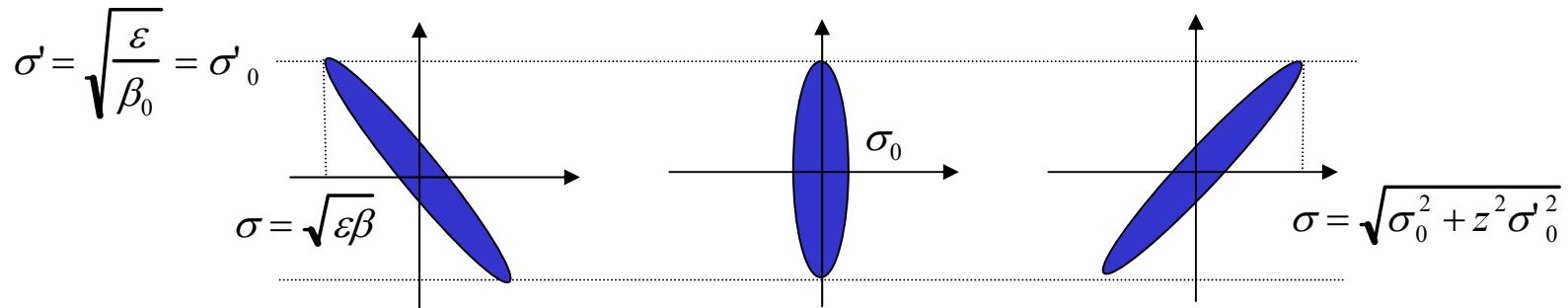


Straight section - free space

Betatron function - describes focusing properties



Phase ellipse propagation in free space



The standard deviations σ, σ' can be expressed in terms of the storage ring parameters ϵ and β

Photon beam phase space

Electron beam origin

$$\sigma_x$$

$$\sigma_{x'}$$

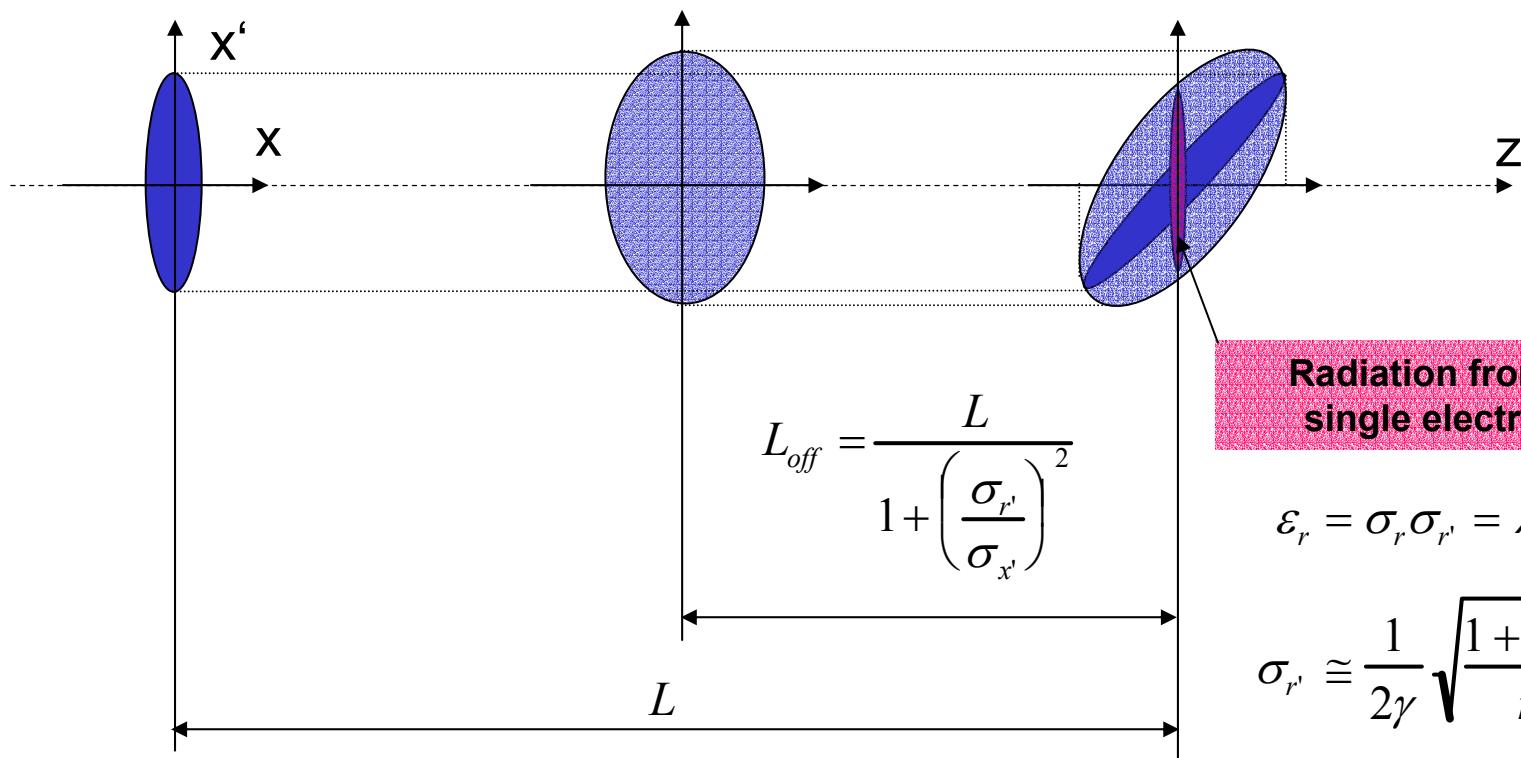
Photon beam origin

$$\sigma_{Tx} = \sqrt{\sigma_r^2 + \sigma_x^2}$$

$$\sigma_{Tx'} = \sqrt{\sigma_{r'}^2 + \sigma_{x'}^2}$$

UNDULATOR

Convolution of undulator radiation from single electron with electron beam



$$\epsilon_r = \sigma_r \sigma_{r'} = \lambda / 4\pi$$

$$\sigma_{r'} \cong \frac{1}{2\gamma} \sqrt{\frac{1 + K^2/2}{mN}}$$

Brilliance

$$B(\mathbf{x}, \phi, z) = \frac{d^4 F}{d^2 \mathbf{x} d^2 \phi} \quad \mathbf{x} = \mathbf{x}(x, y), \quad \phi = \phi(x', y')$$

On-axis brilliance is invariant

$$B(0, 0, z_1) = B(0, 0, z_2) = B_0$$

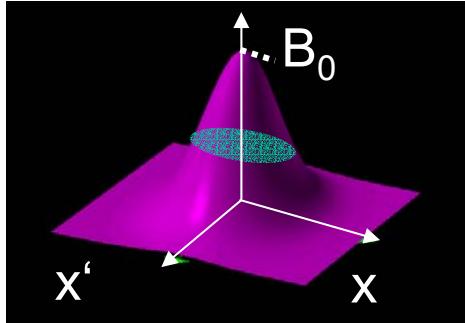
Angular flux density

$$\frac{d^2 F}{d^2 \phi} = \int B(\mathbf{x}, \phi, z) d^2 \mathbf{x}$$

Total Flux

$$F = \int B(\mathbf{x}, \phi, z) d^2 \mathbf{x} d^2 \phi$$

Gaussian beam



$$B(\mathbf{x}, \phi, z) = B_0 \exp \left\{ -\frac{1}{2} \left[\frac{(\mathbf{x} - z\phi)^2}{\sigma_r^2} + \frac{\phi^2}{\sigma_{r'}^2} \right] \right\}$$

$$\frac{d^2 F}{d^2 \phi} = 2\pi B_0 \sigma_r^2 \exp \left\{ -\frac{\phi^2}{2\sigma_r^2} \right\} = \frac{F}{2\pi\sigma_{r'}^2} \exp \left\{ -\frac{\phi^2}{2\sigma_{r'}^2} \right\}$$

$$F = B_0 (2\pi\sigma_r\sigma_{r'})^2$$

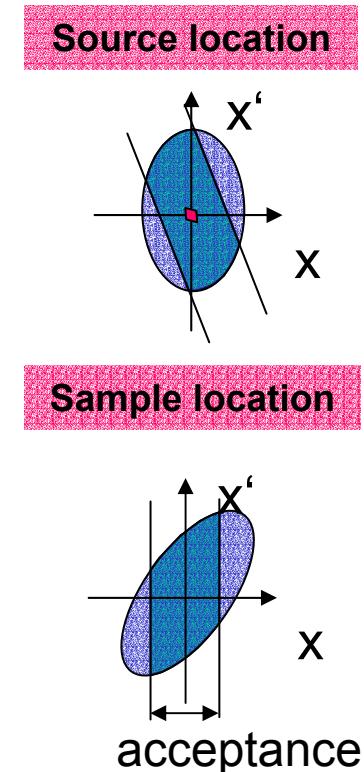
Coherent phase space $\sigma_r\sigma_{r'} = \lambda/4\pi$ \rightarrow Coherent flux $F_{coh} = B_0 (\lambda/2)^2$

Undulator radiation in Gaussian beam approximation

$$B_0 = \frac{F}{(2\pi)^2 \sigma_{Tx} \sigma_{Tx'} \sigma_{Ty} \sigma_{Ty'}}$$

Types of experiments

SR parameters \ Experiment	$\sigma = \sqrt{\varepsilon} \beta$	$\sigma' = \sqrt{\varepsilon} / \beta$	$\varepsilon = \sigma \sigma'$ $(B_0 \sim 1/\varepsilon)$	$\beta = \sigma / \sigma'$
Flux ($\sim I_{SR}$)				
Flux density ($\sim 1/\sigma'$)		$\sigma' \approx \sigma_r$		large
Focusing (flux density)		$\sigma'_T \approx NA$		depends on optics NA
Focusing (spot size)	small			small
Coherence $F_{coh} = B_0(\lambda/2)^2$	small		small $(\varepsilon_r = \lambda/4\pi)$	small



- Storage ring parameters have to be optimized for particular beamline
- Storage ring parameters may need to be modified, depending on experiment
- Optimal storage ring parameters may reduce number of beamline optical components or help to achieve better beam quality

Questions

- Smallest possible electron beam emittance or flexible APS lattice?
- What are the limits of horizontal beta-function?
 - 0.5 - 1 m for small source size
 - 50 -100 m with minimum position located out of the straight section
- How many APS lattices are possible?
 - a beamline may need different settings of storage ring parameters for different types of experiments
- How often can the APS lattice be changed?